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Cities as self-organizing innovative complexes

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Cities: Proximity Matters

Cities are the seedbeds for creativeness, innovation and spatial competitiveness. They are characterized by product heterogeneity and behave according to the laws of monopolistic competition in economics (see Frenken *et al.* 2007). Modern cities try to offer the highest possible quality or image in terms of culture, arts, sports, innovativeness, entrepreneurship, financial markets, sustainability etc. Density and proximity are the key features of modern cities (or, in general, urban areas). The past centuries have been characterized by a structural trend towards urbanization. Some 200 years ago less than 20 percent of the world population lived in cities, whereas nowadays the urbanization degree is moving towards 80 percent. Not only has the number of cities increased rapidly, but also the size of cities. Our world gets more and bigger cities, with a tendency towards megacities which are large urban conglomerates with a global power and a high degree of local /regional economy (Sassen, 1991). Some people wonder whether this trend towards 'more and bigger' might come to a halt. However, from an economic perspective there is no valid argument that would convincingly demonstrate that there is a 'natural limit' to city size. It is plausible to argue that cities will continue to gain importance – in size and numbers – as long as the agglomeration benefits supersede the shadow sides of agglomerations.

When Barbara Ward (1976) held a passionate plea for a positive view on modern cities as 'the home of man', she meant to say that cities are the natural habitat for the human species in the post-industrial period, provided cities would offer favourable living and working conditions as a result of density externalities. Nevertheless, the phenomenon of modern large cities has sometimes prompted contrasting viewpoints and arguments. A clear illustration can be found in the following two quotations which convincingly exemplify diverging perspectives on the urban way of life (see O'Sullivan, 2000):

"Cities have always been the fireplace of civilization, where light and heat radiated out into the dark" (Theodore Parker).

"I'd rather wake up in the middle of nowhere than in any city on earth"(Steve McQueen).

The empirical fact that the majority of the world population is living in cities does not prove that cities are the human settlements par excellence. There are simply too many negative voices on the functioning and the future of our cities. And Glaeser (1998) has in an interesting survey article correctly questioned whether cities might be dying. His analysis shows a straightforward result: cities are able to generate unprecedented economies of scale, and as long as agglomeration advantages are higher than their counterparts, cities will continue to be magnets of human activity.

Clearly, the demarcation of different city concepts in various parts of our world may be problematic, and there may be significant differences between megacities, megalopolises, urban areas, urbanized areas, edge cities, metropolitan areas and the like. Most likely, it is not the statistical definition which tells us the full story, but the question how much citizens in a certain settlement configuration share an urban way of life. In other words, adherence to a certain life style (creativity, individuality, mobility, global orientation etc.) belongs to the human ecology of an urbanized world.

It goes without saying, that any urban way of life has to be supported by a proper set of values, cultural behaviours and infrastructures which act as determinants of an urban culture, not only for the residents of the city but also for business life. A city forms a complex ramification of many socio-economic forces that shape a seedbed for creative and innovative lifestyles. The relationship between business life and the city is often underrepresented in urban economics, but deserves full-scale attention. The growth and decline of business firms is critically contingent on urban seedbed and incubator conditions, knowledge production and adoption, creativeness and business potential, and adoption of a modern business lifestyle and culture in a digital economy (see also Acs, 2002; Bögenhold *et al.*, 2001; Romein and Albu, 2002; Sexton and Smilor, 1986).

In recent years, the ICT sector is often seen as a major initiator of new activities. We have witnessed an upsurge of entrepreneurial initiatives closely connected with the rapid growth of the ICT sector (see, e.g., Cairncross, 1997; Cooke and Wills, 1999; Ohmae, 1999). In the industrial organization and management literature, much attention has been given to participation in, and access to, formal and informal networks as strategic mechanisms for creating increasing returns in an uncertain dynamic urban business environment (see, e.g., Borgatti and Foster, 2003; Hoang and Antoncic, 2002; Malecki, 1997; Schiller, 1990). It is generally recognized that modern dynamic sectors of the economy, in particular the ICT sector, have the potential to generate high returns, though often in a risky business environment. Access to knowledge and information is usually seen as a key factor for success in a risky entrepreneurial context. Clearly, an urban environment offers often a reduction in business risks through a dense (formal and informal) information network.

It is now an important question whether, in our age of advanced telecommunication, contact intensity and business access is best served through physical proximity of people and firms, or whether modern ICT systems create virtual connectivity without the need for geographic proximity. There have been many speculations on the death of distance and on the space-opening character of the advanced ICT sector (for a review, see e.g. Cohen *et al.*, 2004; Van Geenhuizen and Nijkamp, 2007). But what are the empirical facts concerning the needs of business firms for geographic juxtaposition in the urban economy? And what are the costs of ICT-instigated urban sprawl (Travisi and Camagni 2005)? Does ICT favour footloose behaviour of firms, or will it reinforce urban agglomeration forces? How does urban infrastructure contribute to a better access or proximity? And what is the role of knowledge networks in proximity?

'Proximity' is a frequently used concept in geography, but it has different connotations. First, there is physical proximity in terms of a short straight-line distance or a short distance based on using a transport network. In fact, what matters in interaction is the time or efficiency in bridging such a distance. Geographic proximity is either a physical or a time concept, or both. However, in a social space there is also social proximity, *i.e.*, a perceived small distance as a result of impacts from social relationships, common habits and interests etc. (see, e.g., Gertler, 2003).

Clearly, both concepts may be intertwined in an urban area.

Cities can be seen as agglomerations of economic activities based on advantages of both kinds of proximity. In conclusion, the urban mode of living and working calls for an explanatory framework that is able to encapsulate the motives and behaviours of their citizens and firms. However, a single paradigm that would allow us to understand the complexity of urban life from an unambiguous perspective does not exist. The relationship between complex urban growth and urban infrastructure is also at stake here. Instead, as we will argue in the next section, there are rivalry paradigms that all aim to uncover (part of) the multi-faceted and complex urban reality, where cities exert both centripetal and centrifugal forces.

Cities as Magnets: Different Perspectives and a Systems Economics View

Cities are complex socio-economic systems that have been studied in the literature from various angles. We will offer here a concise overview.

Urban Systems Economics

In a modern and global network society cities have adopted the role of strategic hubs. The changing role of cities has also prompted various new concepts, such as 'global cities' (Sassen, 1991), 'global city-regions' (Scott *et al.*, 2001)) and 'world city networks' (Taylor, 2004). Many cities have witnessed an upsurge of vitality and innovativeness, whereas others have shown signs of decline or stagnation. Despite serious doubts expressed by scholars all over the world on the feasibility of an urban world, cities and their surroundings have become magnets of innovation, creativity, leadership and business activity. There is a great variety of analysis frameworks that have aimed to offer a motivation for the emergence of urban culture and urban agglomeration forces. We mention a few:

- A *market-oriented view*, in which the urban rent gradient is the spatial-economic representation of the supply and demand for urban land by different categories of users, while taking into consideration density externalities (advocated inter alia by classical authors like Alonso, Muth, Henderson etc.)
- An *ecological socio-cultural view*, in which a blend of sociological and organistic urban viewpoints is offered to explain the structure of urban living and working patterns (advocated in particular by the so-called Chicago School).
- A *clustering and industrial networks view*, in which urban dynamics is analysed from the perspective of a multiplicity of conflicting interests of urban stakeholders (outlined by advocates of the so-called Los Angeles School, such as Scott and Storper).
- A *politico-economic power view* on cities, in which in a globalizing world large cities act as global command centres with centripetal and centrifugal forces all over the world (advocated inter alia by Sassen).
- An *agglomeration advantage view*, in which urban agglomerations generate overwhelming

advantages of scale and scope, so that cities become by necessity strong players in the space-economy (advocated inter alia by Glaeser).
- A *creativity view* on urban life, in which cities are the source of rejuvenation, innovation, radical breakthroughs and permanent change, as a result of the leading role of the creative class (see e.g. Florida).
- A *virtual cities perspective*, in which in an emerging digital e-society cities act as key nodes in a virtual network and exploit all agglomeration benefits of their territory in a world-wide arena (advocated inter alia by Graham and Marvin).

This eclectic overview of various strands of literature is by no means complete and offers a varied and fragmented impression. And there is undoubtedly a clear need and scope for a more integrative perspective based on a systemic view on the city. Clearly, urban economics has become in the past decades a respected discipline with a rigorous analytical toolbox. But its weakness is its stylized focus and narrow focus coverage which reduces its operational meaning and its policy relevance. Taking the economics discipline as a nucleus surrounded by various other disciplines functioning as satellites, we may be able to create a theoretically sound and methodologically consistent analysis framework which might be coined a systems economics approach. Similar developments are nowadays found in systems biology, cognitive sciences and bio-physics. Systems economics would be characterized by various features:

- it offers a multi-disciplinary focus;
- it is multi-actor oriented with emphasis on interactions;
- it covers economic systems from micro- to macro-analytical perspectives in a multi-layer way;
- it is essentially dynamic and based on evolutionary complexity;
- it is analytical-quantitative in nature in order to map out key drivers and their impacts on complex systems.

Such an approach might have great merits for the analysis of cities as complex systems. Urban systems are – from the viewpoint of systems economics – characterized by three particular and distinct features, viz. the existence of density externalities, the dependence on its (physical and cultural) resource base, and the importance of interactive dynamics accruing from learning (including evolutionary and creativity) principles. These three features will now concisely be presented and discussed.

Density Externalities

In the history of urban economics much attention has been paid to density and proximity externalities (Hoover, Isard), where often a distinction was made between scale, localization and urbanization economies. The density externalities perspective takes for granted that urban size has no limits, as long as the economies of density overshadow the diseconomies. According to the density externalities framework, cities offer prominent socio-economic and cultural advantages that are far higher than any other settlement pattern. In particular, in our modern age cities offer spatial advantages related to knowledge spillover effects and an abundant availability of knowledge workers in the labour market (Acs *et al.*, 2002). Spatial concentration of activities, involving spatial and social proximity, increases the opportunities for interaction

and knowledge transfer, and the resulting spillover effects reduce the cost of obtaining and processing knowledge. In addition, knowledge workers preferably interact with each other in agglomerated environments to reduce interaction costs, and they are more productive in such environments (Florida, 2002). Following this argumentation, cities are the cradle of new and innovative industries. Companies in the early stages of the product and company life cycle - when dealing with manifold uncertainty - prefer locations where new and specialized knowledge is abundantly available for free (see e.g. Audretsch, 1998; Camagni, 1991; Cohen and Paul, 2005). Cities offer an enormously rich potential for a wide array of business opportunities.

Clearly, the spatial extent of knowledge spillovers is limited due to various kinds of geographic impediments, e.g., a wide daily activity system where people can meet easily and where people change jobs in the course of their careers, or smaller areas such as quarters in a central business district or university premises where people see each other often by chance (e.g. Rosenthal and Strange, 2001). The need for spatial proximity to benefit from knowledge spillovers seems, however, at odds with the impacts of the recent telecommunication revolution, *i.e.* the costs of electronic communication have drastically declined, while advanced ICT allows for long-distance videoconferencing, data-mining, virtual design, computer-assisted decision making, etc. ICT offers an unlimited spectrum of virtual communication opportunities. But does it affect urban size?

To understand this paradoxical situation on the geography of knowledge spillovers we need to look into the type of knowledge concerned (Howells, 2002). On the one hand, there is codified knowledge (partly just information) that can easily circulate electronically over large distances, e.g. prices determined at a stock exchange and statistical data. On the other hand, there is tacit knowledge and its context, and these are critical in innovation processes. The knowledge concerned is vague and difficult to codify and, accordingly, spreads mainly through face-to-face contacts of the persons involved. Tacit knowledge is transferred through observation, interactive participation and practice. Furthermore, there is contextual knowledge, which is achieved through long-term and interactive learning, often in relatively open (unstructured) processes (Bolisani and Scarso, 2000). All such density externalities present in a modern city offer a very powerful tool for cities to survive and to grow and to become hubs in a space-economy.

Resource Base

Cities are strongly dependent on their resource base. In the past, it was mainly the physical geography that determined the location of cities (riverbanks, seashores, strategic areas in a country, presence of natural resources such as coal or water). In the past decades, industries have become much more footloose, and consequently the meaning of the physical resource base for cities has declined. But in the meantime, cultural and knowledge resources have assumed a more prominent position.

According to the modern resource-based perspective, the local capabilities and urban seedbeds are decisive for the relatively strong position of cities, especially from a business perspective. In the view of resource-dependence theories, it are particularly young and innovative entrepreneurs who have articulated needs for new knowledge, *i.e.* knowledge about the technology concerned and knowledge to deal with the market, but they cannot generate this knowledge by themselves

(see e.g., Lockett and Thompson, 2001; Reid and Garnsey, 1998). In this context, Storper and Venables (2002) distinguish between various functions of tacit knowledge transferred in cities, e.g. for coordination, confirmation and checking, and for monitoring. In modern versions of resource- dependence theory it is taken for granted that companies make use of various bundles of resources on a temporary basis, including knowledge, capital, employees and networks, to generate profits. Success in generating profits depends both on their own capabilities and the supply of resources in their environment (e.g., Barney, 1991). The growth of companies is constrained if there is a shortage or weakness in the available resources, or in the capability to mobilize or generate adequate resources. Reid and Garnsey (1998) distinguish between different stages in growth, ranging from achieving access to resources to the mobilization of resources, and companies' own generation of resources. The use of the right combination of resources at the right time by young, innovative entrepreneurs enables them to undertake a jump in growth. Failing to use the right combination at the right time may cause a delay in growth and even a fall back into previous stages (Vohora *et al.*, 2003). In the early growth stages and after a fall back to such stages, companies may rely heavily on resources available in the environment, including the urban environment and its constituent infrastructure and suprastructure.

The resource-based theory prompts of course intriguing questions on footlooseness of firms. There is not much conceptualization of the situation in which companies are free from location constraints. The term 'footlooseness' is often used in this context, but it is poorly conceptualized with regard to companies. An early use of the term 'footloose' can be found in the work of Klaassen (1967). Accordingly, an industry is footloose, if its long-run profitability is the same for any location in an economy. However, this is quite a rigorous definition that excludes different degrees of footlooseness. Here, we may consider footloose as the situation at one end of a spectrum, with location- or place-bound at the other end. This makes it possible to distinguish various degrees of footlooseness and to emphasize the relative character of footlooseness. Thus, 'being increasingly footloose' means, in the discourse on agglomeration economies, that particular constraining factors that were active in the past, such as the need for proximity to knowledge institutes, specialized suppliers and specialized labour, decrease in importance, thus allowing companies to choose a location under higher degrees of freedom within a certain spatial area (see Van Geenhuizen and Nijkamp, 2007). Note that footlooseness is often relative to a particular area or scale under consideration. For example, companies may be footloose with respect to their city region, but not with respect to the national system or continent. Clearly, communication, transportation and transaction costs are decisive factors for firms to choose a logistic and locational option in a competitive spatial-economic context. In summary, resources – defined in a broad sense – are decisive for the city's location and performance.

Learning, Creativity and Evolution

The rationality paradigm has exerted a great influence in urban economic analysis, but has often failed to explain jumps and anomalies in urban systems. Research in the social sciences is at present increasingly influenced by evolutionary perspectives, notably learning perspectives. Since the early 1990s concepts such as learning regions, smart cities, creative cities, science-based

regional development, etc. have received an increased attention among regional economists, economic geographers and regional policymakers. This development marks the recognition that factors determining economic growth of regions (cities) are increasingly intangible, like institutions and culture, and increasingly mobile, like capital, codified knowledge, and – in part - human capital. It also reflects the awareness that innovation by companies is not a linear process, running from invention and commercialization to market introduction, but a cyclic and interactive process within networks of many different actors. In this view on innovation, emphasis is increasingly put on diversity of the networks and boundary-spanning activity of the network actors. Learning in this context not only means to adapt to new circumstances, like a stronger competition, but also to reflect critically on the own institutions and learning processes. In a positive scenario, the networks consist of loosely coupled relations that enable openness and integration, and create perspectives for action. In a negative scenario of "lock-in", however, networks become conservative and inward-oriented - thereby preventing any learning-based action - or they become subject to confusion leading to high transaction costs and inefficient adaptation (see also Acs *et al.*, 2002). In other words, the quality of the network dynamics strongly matters; but much remains unknown to date, like about key influences on network dynamics and turning points in the quality of the networks. This calls for additional and intensified social science research.

One of the first regional scientists who addressed the learning region as a paradigm is Florida (1995). Earlier seminal work underlying the learning regions paradigm was done by Aydalot (1986), Camagni (1991), Maillat (1991) and others, while the paradigm was fertilized from different angles in regional studies, like the ones on innovation systems, technology complexes (including knowledge spillover phenomena), post-Fordism and clusters, and the ones on technology policy, local and regional institutions and community action (see e.g., Benner, 2003; Morgan, 2002; Ratti *et al.*, 1997; Cooke, 1998; Maskell and Malmberg, 1999; Gertler and Wolfe, 2002). The learning regions approach has the advantage over other approaches that it explicitly addresses the quality of policymaking and of other institutional conditions in the regional economy and society. In particular, it is a regional development concept in which the emphasis is put on improving individual and collective learning processes of the regional actors involved through open and flexible networks (OECD, 2001). This concept does not implicate that the learning is exclusively taking place between regional partners. Regional actors (e.g., policy institutes and companies) learn through both regional (local) and global networks.

Many governments today deliberately try to enhance high-technology activity in their regions and often embrace the learning regions paradigm to improve policymaking. However, there is a long way to go and the path is littered with stumbling blocks. Barriers in policymaking reside in policy organizations themselves and in the nature of knowledge policies. A framework that can be used in clarifying these issues, is given by evolutionary approaches. Evolutionary thinking allows for an explanation of qualitative change, the rise of radical uncertainty, the role of institutions in reducing uncertainty, variation between organizations and technology, and it provides useful notions for a better understanding of policymaking under such circumstances (Saviotti, 1997; Van den Bergh and Fetchenhauer, 2001). Learning appears to become an increasingly powerful paradigm in understanding urban dynamics against the background of urban competition in a struggle for survival. Slow evolutionary dynamics and infrastructure provision are two closely connected phenomena here.

In conclusion, the rise and death of (mega)cities may be interpreted from different perspectives, each with its own merits and validity. These angles are not necessarily conflicting, but rather mutually complementary. But a critical question remains under which conditions urban growth – or urban revitalization – is a sustainable outcome. Which are the lessons taught by standard textbook urban economics? This will be the subject matter of Section 3.

Urban Economics

Urban economics is at the core of regional science and has contributed significantly to a better understanding of the urban system, thanks to the works of Von Thünen, Christaller, Alonso, Muth, Isard and many others. The straightforward economic analysis of urban land use in the presence of competing actors (various income groups, business life etc.) have led to a wealth of ideas and insights on price formation of urban land and the related location patterns of actors in the city (see also Capello and Nijkamp, 2005).

The interactive structure of the urban space-economy has generated many externalities which are decisive for continued urban economic growth (see also Smit, 2007 for a meta-analysis of the determinants of growth in cities). In the literature very often a distinction is made between three types of externalities in the city:

- Urbanization and localization economies often referred to as Marshall-Arrow-Romer (MAR) externalities; these externalities are closely associated with specialisation economies.
- Synergy economies that originate from cultural and socio-economic diversity in the city (often referred to as Jacobs externalities); such externalities are based on social learning mechanisms in an urban 'melting pot'.
- Competition economies that are related to the need to do novel things if there are many competing business actors in the same city, often referred to as Porter externalities.
- The various economies of density in the city do not only have direct economic dimensions (such as efficiency and productivity aspects), but also spatial aspects ('principles') in a broader regional and (inter)national context (Camagni, 1992):
- *Agglomeration principle*: the high density of production and residential activities in the city – based on physical proximity – creates special territorial forms of the city (e.g., on the basis of concentric patterns stemming from rent gradients).
- *Accessibility principle*: the interactions between transport costs and land use form the basis for urban mobility patterns.
- *Spatial interaction principle*: the intensive and frequent contact potential between urban actors induces various forms for density economies and related spatial implications.
- *Urban hierarchy principles*: socio-economic heterogeneity in the city creates a socio-economic and territorial division of labour and residential patterns and hence induces socio-economic disparity.
- *Competitiveness principle*: cities are breeding places of new ideas and call for permanent business innovations which require tailor-made spatial provisions in favour of urban efficiency mechanisms.

The number of research challenges on modern cities is vast and urban economic has developed a series on analytical methodologies to cope with these emerging issues. Examples are studies on 'optimal city size' (nowadays often referred to as 'efficient size'), functional specialization of cities in a global competition, the use of social capital in cities, spatial organization in the context of systems of cities etc. These new research directions are often summarized under the heading of '*New Urban Economics*' or '*Analytical Urban Economics*' (see Richardson *et al.*, 1996). The main novelty was to introduce more realistic assumptions and to address also urban policy issues (e.g., income distribution, consumer heterogeneity, congestion externalities, segregation, criminality, labour market and unemployment issues etc.). Furthermore, the scope of urban economics research was extended towards other domains, such as transportation (see e.g., Nijkamp and Reggiani, 1999), city networks (see Camagni, 1993) or environment (leading to a vivid debate on sustainable cities).

In the past decade, much attention has also been given to urban growth in relation to agglomeration economies, with a particular view to the determinants of growth in a complex spatial setting (e.g., industrial specialization, infrastructure endowment, central location in a network etc.) which are closely related to scale economies and non-linear spatial network phenomena. This may lead to unstable behaviour in urban development and even to multiple equilibria (see e.g., Krugman, 1991).

In the same vein we have observed an increasingly popularity of endogenous growth theory, in which knowledge, innovation and infrastructure play a key role in urban development (see e.g., Romer, 1986, 1990; Lucas, 1988; Nijkamp and Poot, 1998; Stimson *et al.*, 2002).

New methodological research directions in urban economic were addressing urban dynamics by using ideas from spatial complexity theory, in which inter alia non-linear evolution, chaos principles, synergics, evolutionary biology, and learning algorithms play a critical role (see Nijkamp and Reggiani, 1999). In this context, there is also due attention for innovation, creativity, entrepreneurship and leadership.

The various trends sketched above point at various directions in urban economic research: increase in realism, systemic complexity, and spatial networks orientation. There seems to be a need for a new wave of analytical efforts that would study cities from a computable equilibrium perspective, with a balance between (i) growth-inducing and growth-hampering factors, (ii) multiple (from micro to macro) layers of actors and structures in a city, and (iii) intra-urban and extra-urban force fields. Against the background of these observations, a plea for a complex urban growth theory seems warranted which may lead to the design of the above mentioned systems economics approach to cities, with sufficient attention for the negative externalities of urban development.

The Shadow Sides of Modern Cities

The previous sections have extensively argued that cities are based on the existence of a multiplicity of density economics, which generate a wealth of positive externalities inducing urban growth. But cities have clearly many shadow sides, such as congestion, low-quality environmental conditions, social stress and segregation, high crime rates etc. Such negative

externalities have to be coped with in order to keep the net balance between positive and negative externalities positive. From the perspective of urban policy, a new endogenous growth model may be developed in which the endogenous forces for enhancing growth potentials (e.g., knowledge infrastructure) and for reducing environmental threats (e.g., environmental taxation) are combined in one analytical framework (Verhoef and Nijkamp, 2008).

The attention for urban environmental conditions and the urban ecology has prompted a movement towards sustainable city development which would lead to a balance between positive and negative urban quality conditions (see Table 5).

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Agglomeration economics Specialization and diversity R&D and innovation Physical capital (Spatial hub)	Urban deterioration Diseconomies of agglomeration Unemployment Exclusion and poverty Socio-economic inequalities Immigrants Criminality Congestion Poor-quality infrastructure

Table 5 - Sustainable urban development: a shaky balance between positives and negatives (OECD, 2006)

Table 5 confirms the need to identify and measure the relevant conditions (both positive and negative) that impact on local sustainability quality. It prompts challenging questions for urban policy-makers to arrive at optimal quality conditions for cities. Clearly, there is an enormous variety in environmental quality conditions world-wide. A series of interesting findings over a period of 15 years was recently published in a monitoring study of the Asahi Glass Foundation (2007). Table 6 maps out the most pressing local environmental problems as perceived by hundreds of interviewees/experts world-wide. This table leads to two important conclusions: waste and urbanization/transportation are generally regarded as the most important sustainability problems in cities in the industrialized word, while poverty is seen as a very prominent issue in cities in the developing world.

Next, Table 7 offers a further decomposition of Table 6 and indicates which items in local waste management deserve high priority. It appears that active recycling policy and active waste policy (incl. toxic materials) are seen as high priority areas, with only small variations in different regions of the world.

A further decomposition of priority areas is given in Table 8, where the second most pressing environmental issue is further analyzed, viz. urban transportation problems. Congestion, infrastructure design and use, and environmental decay from transportation are seen as the most important problems, with quite some variation in interest among the various world regions distinguished.

Finally, the most pressing environmental problems related to urbanization are presented in Table 9. It turns out that there are four prominent concerns, viz. waste, air and noise, natural systems and water, and urban sprawl. The first two items are mainly showing up as major concerns in Japan, Asia-4, Eastern Europe and the Middle East, while urban sprawl is regarded as a major problem in both Western Europe and the USA/Canada.

The previous observations have clarified that sustainable city development policy is a multi-faceted task which calls for a broad ecological view on the city in relation to its surroundings. Given the general trend of urbanization in the developed world, it is plausible that the ecological stress on cities will increase in the future, so that the challenge of urban sustainability will likely rise in the years to come. This development seems to prompt two routes for action: effective ecological policy for our cities (e.g., strict regulatory schemes on parking, industrial development, waste management, effective urban green policy etc.) and flanking policies supporting an innovative development of cities geared towards a high competitiveness (e.g., cultural and creativity policy, innovation and knowledge policy etc.). It is mandatory for a sustainable city policy to develop innovative perspectives, so that economic progress is not at odds with sustainability development, but supports an effective socio-economic and ecological resilience in modern cities. This challenge will be further discussed in the next section.

Region	Waste Management	Waste Management	Poverty	Other
Japan	**	*		
Asia-4	**	*		
East Eur	**	*		
Mid East	**	*		
West Eur	*	**		
USA/Can		**		*
Africa	*		**	
Rest Asia	*		**	
Lat Amer			**	*
Ocean				**

Table 6 - Most pressing environmental problems (2006)

Region	Active recycling	Active waste policy
Japan	*	**
Asia-4	*	*
East Eur	-	*
Mid East	-	-
West Eur	*	**
USA/Can	*	*
Africa	-	-
Rest Asia	-	-

Table 7 - Priorities of local waste management (2006)

Region	Congestion	Infrastructure	Environmental decay
Japan	**		*
Asia-4	*		**
East Eur	*	**	
Mid East	*	**	
West Eur	**		*
USA/Can	*	**	

Table 8 - Most pressing transportation problems (2006)

Region	Waste	Air and noise	Natural systems & water	Urban Sprawl
Japan	**		*	
Asia-4		**		*
East Eur		*	**	
Mid East	**		*	
West Eur		*		**
USA/Can	*			**

Table 9 - Most pressing urban environmental problems (2006)

The Counterbalance: Productivity is the Key!

Solid economic development of cities is a prerequisite for their sustainable development. But which factors are decisive for a flourishing and vital urban economy? In a recent OECD study (2006) several key drivers have been analyzed and identified. It turns out that productivity per worker in the city is a critical success factor. It outstrips other factors, such as efficiency of the local labour market (employment/unemployment ratio) and the activity rate (labour force with respect to total population). The OECD study concludes that urban productivity differences determine whether the per capita income in a given urban area falls below or stands above the average (see Van Hemert *et al.*, 2007). These findings are illustrated in Table 10. This figure demonstrates that in particular US cities have a relatively high productivity, whereas developing countries and semi-developed countries have a much lower performance. European cities appear to assume an intermediate position.

Winners	Intermediate	Losers
Boston	Frankfurt	Istanbul
San Francisco	Stuttgart	Krakow
New York	Stockholm	Ankara
Washington	Munich	Daegu
San Diego	Sydney	Izmir

Table 10 - Comparison between cities

The determinants of urban productivity differences are manifold, but two factors are generally assumed to be of decisive importance, viz. an advanced knowledge infrastructure and a high ICT orientation (see Black and Henderson, 1999; Brinkley and Lee, 2006, and Henderson *et al.*, 1995).

The previous findings are supported by Table 11, which presents the investments in knowledge in various OECD countries (1994-2002). Knowledge may be seen as a trigger of many new, vital and innovative developments in urban areas (which may in general be regarded as knowledge hubs in a knowledge-based society) (see also Glaeser and Mare, 2001).

% of GDP	1994	2002	CHANGE
WORLDWIDE			
US	5.4%	6.6%	+1.2
Korea	4.9%	5.9%	+1.0
Japan	3.9%	5.0%	+1.1
Canada	4.5%	4.7%	+0.2
Australia	3.9%	4.1%	+0.2
EUROPE			
Sweden	5.1%	6.8%	+1.7
Finland	4.7%	6.1%	+1.4
Denmark	3.7%	5.5%	+1.8
Germany	3.4%	3.7%	+0.3
Belgium	3.6%	3.8%	+0.2
Netherlands	3.4%	3.8%	+0.4
France	3.4%	3.7%	+0.3
UK	3.5%	3.7%	+0.2
Austria	2.3%	3.4%	+1.1
Spain	2.1%	2.8%	+0.7
Ireland	2.6%	2.4%	-0.2
Italy	2.0%	2.4%	+0.4
Greece	1.1%	1.9%	+0.8
Portugal	1.3%	1.8%	+0.5

Table 11 -Investment in knowledge in OECD countries

As mentioned before, cities are marked by a high degree of heterogeneity in terms of consumption behaviour, productivity, business profile or labour market conditions. Figures 4 and 5 present some comparative data on employment growth and growth in gross value added (GVA) in various European metropolitan areas during the period 2001-2004. There is indeed quite a disparity in employment growth and GVA growth among European cities. There is no doubt a backlog and catch-up effect, e.g., Dublin. Furthermore, a comparison between Figure 4 and 5 teach us, that these figures display of course some variation, but also a surprising correspondence between the rankings of various cities.

It seems plausible that investments in knowledge and human capital create vital cities. Urban revitalization and sustainability are necessary for European cities to keep up with major players in the world. Pro-active strategies to avoid path dependencies and lock-in situations are certainly necessary for cities in Europe (see Bock, 2006).

Infrastructure and suprastructure may be seen as two major push factors for urban dynamics, as has convincingly been argued in the literature. An optimal provision of infrastructure and suprastructure – sometimes also coined social overhead capital – is usually seen as critical success factors for economic growth, both nationally and locally. An important starting point for a thorough analysis of the above issues was given almost fifty years back by Hirschman (1958) who in his investigation into the strategy of economic development convincingly demonstrated that social overhead capital is a necessary but not sufficient condition for economic progress. The main task of public policy is to address the balance between directly productive inputs and social overhead capital, where an optimal allocation of both types of factor inputs can be based on neo-classical cost-minimizing production theory. Unbalanced growth may then be the result of a lack of fine tuning between directly productive capital and social overhead capital.

In Hirschman's view social overhead capital has a fairly broad meaning; it is usually public capital which is normally characterized by lumpiness and indivisibility and does not have an

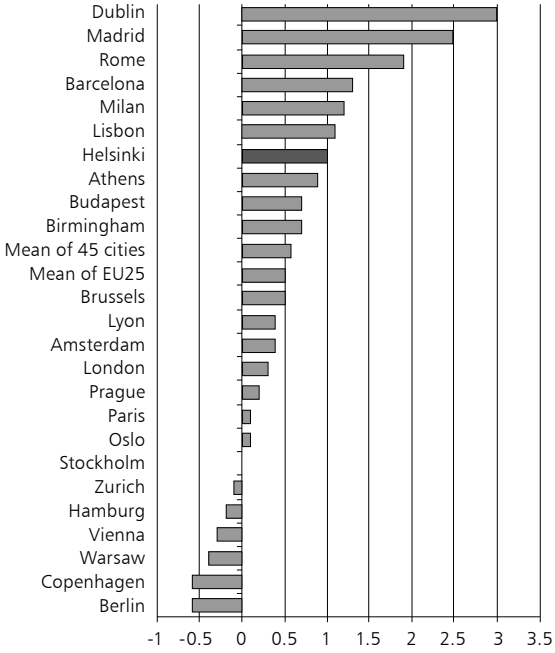

Figure 4 - Employment growth in European metropolitan areas (2001-2004)

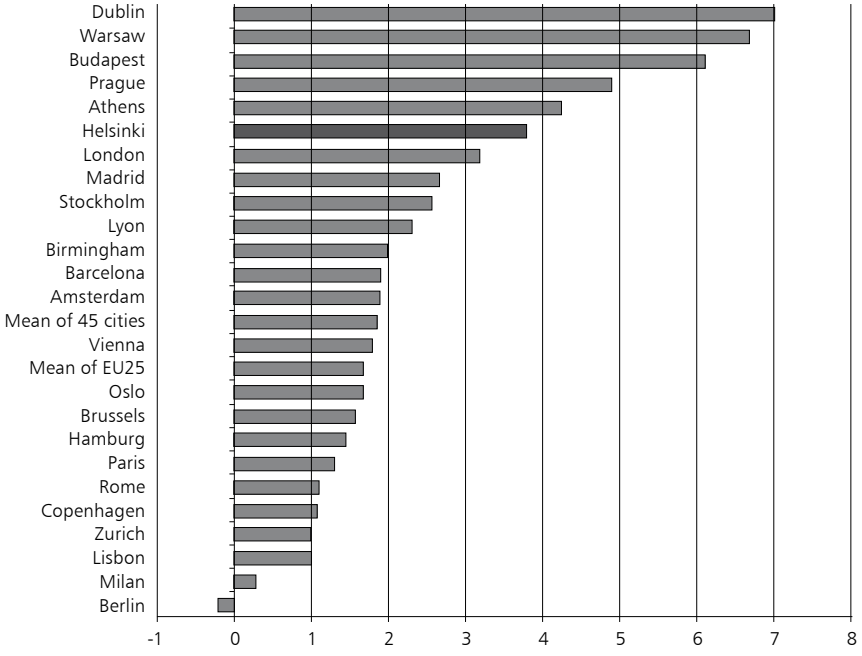

Figure 5 - Economic growth (GVA) in European metropolitan areas (2001-2004)

immediately productive character (in contrast to labour or capital). It may be either material in nature (roads, railways, (air)ports, pipelines etc.) or immaterial (knowledge networks, communication, education, culture etc.). The first class will be called here *infrastructure*, the second one *suprastructure* (see for an extensive overview of social overhead capital also Wilson *et al.*, 1966; Youngston, 1967; Nijkamp, 1986; and Lakshmanan, 1989).

In a more pronounced spirit than Hirschman, Rostow (1960) has argued that transport infrastructure is of decisive importance for economic development, witness the impact of railroads on economic growth in many US states. In regional development theory the main emphasis has been placed in the past decades on the physical (or material) components of social overhead capital, *i.e.*, on *infrastructure*. Several focal points can be distinguished in the analysis of the importance of infrastructure for regional and urban development. In the first place, a main focus is on the removal of *bottlenecks* in the development of a single region or city in order to improve its accessibility (e.g., the construction of a bridge, tunnel or railway connection) (see e.g., Mera, 1973; Looney, 1992; and Bruinsma *et al.*, 1996). Later on, the attention was also devoted to the instrumental role of infrastructure in removing structural interregional *inequality* conditions (see e.g., Blum, 1982; Nijkamp, 1986; Williams and Mullen, 1992; and Biehl, 1995). And more recently, this equity argument has been extended towards a broader analysis of *interregional and interurban competitiveness* conditions, in particular in view to the acquisition of foreign direct investments (see e.g., Conrad and Seitz, 1997; Van Geenhuizen and Nijkamp, 1998; Nijkamp, 1993 and Ozawa, 1992).

In recent years, also the relationship between infrastructure and suprastructure (in particular, overhead capital in favour of innovativeness and knowledge use) has intensively been studied (see also Acs *et al.*, 2002 and Capello, 1996). Suarez-Villa and Hasnath (1993) and Suarez-Villa (1996) have argued that in the US some convergence can be found between the long-term upswings and downturns of both infrastructural investment and innovative capacity, while they also identified a remarkable association between educational infrastructure provision and (both aggregate and corporate) innovative capacity. Apparently, the growth potential of an area is influenced by both infrastructure and suprastructure provisions.

The overall findings on the positive correlation between infrastructure and suprastructure supply and economic development are not always conclusive, although they seem to be more convincing at a macro level. An attempt at a systematic cross-sectional comparative study of such impacts based on meta-analysis is found in Button and Rietveld (1998), while a broad overview and various empirical case studies can be found in an interesting study of Rietveld and Bruinsma (1998).

Infrastructure and suprastructure are a complex and polyvalent phenomenon. The importance of *synergetic effects* between various types of infrastructure – which is based on network connectivity (intermodality, interoperability, e.g.), has sometimes been recognized at a theoretical level, but in operational multiregional economic models the occurrence of such synergetic effects is usually neglected. This synergy has more weight, if also the information and telecommunication sector offers an added value to advanced infrastructure.

Furthermore, most models have been formulated as tools for spatial impact studies: a change in infrastructure is supposed to lead to a change in the private sector in a given area. Infrastructure is then usually an exogenous variable in these models. This is not necessarily

an adequate way of modelling infrastructure. As shown in the *endogenous* growth literature, infrastructure may not only influence the private sector, it may also be stimulated by the revenues of the private sector after a first round of improvement. It is challenging to broaden the scope of such models by introducing the possibility of this two-sided relationship, e.g., in a CGE context.

It should be added that the assessment of the impact of suprastructure on urban growth is not easy. There are several studies on the impact of universities of educational institutions on urban development, but a more integrated analysis of a comprehensive suprastructure on the city is very rare. In the spirit of our above mentioned exposition, it is clear that urban agglomeration advantages reinforce the impact of urban suprastructure on urban development.

Finally, a particular kind of suprastructure that has gained much popularity in recent years is creativity suprastructure. Since Florida's ideas on the creative class, the creative industry and the creative city (see for an overview Florida, 2002), an avalanche of studies has been undertaken to study the features and success conditions of creative environments (see e.g., Gabe, 2006; Heilbrun and Gray, 1993; Hesmondhalgh, 2002; Landry, 2003; Markusen, 2006; Power and Scott, 2004; Pratt, 1997; Scott, 2003; Vogel, 2001). Despite several empirical studies, an operational conceptualization of creativity infrastructure and suprastructure has as yet not been developed and calls certainly for more profound applied research. This is once more important, as there is a growing awareness of and interest in the dynamics-enhancing impact of creative activities.

On the basis of the foregoing observations we may argue that modern cities exhibit an unprecedented dynamics in terms of their economic performance, functional hierarchy and linkage structure, and socio-cultural behaviour. But their role as central hubs in a dynamic space-economy has been remarkably robust. This phenomenon of stability and change calls for further intellectual efforts to come to grips with urban complexity. Such a systems-economic oriented perspective will be offered in the next section.

Cities as Self-Organizing Innovative Complexes

Urban developments exhibit complex change patterns, with sometimes irregular fluctuations and chaotic movements. These are not determined by anonymous forces, but are the result of a highly complex force field. In other words, urban resilience and sustainable growth are not the result of a rectilinear movement, but are influenced by a great variety of intra-urban and extra-urban factors. Dynamic cities are to be regarded as innovative species struggling for survival under conditions of internal threats and external challenges. 'Challenge and response' forms an adequate description of the dynamics of our urban world. In most cases, modern cities have to organize themselves in an effective and efficient way in order to cope with both regional and global competition. This means essentially that modern cities may be conceived of as 'self-organizing innovative complexes' (SIC) that are subject to the conditions of systems dynamics. The generic features of such urban or metropolitan SIC are:

- a reliance on creativity, innovativeness and leadership
- competitive advantages to be created by R&D
- productivity and competitiveness as critical success factors

- a market orientation determined by product heterogeneity and monopolistic competition
- a development path marked by evolutionary complexity and behavioural learning principles.

Despite the multidimensional complexity of modern cities in their struggle for progress and sustainability, we may distinguish a limited set of systematic factors that exert a decisive impact on the socio-economic and ecological performance of these SIC. These factors which call essentially for an urban systems economics perspective are summarized in Figure 6 in a so-called Pentagon model.

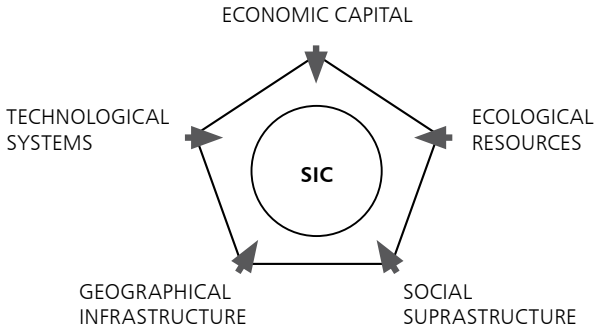

Figure 6 - A Pentagon model of critical forces for SIC

The Pentagon model has demonstrated its methodological power and empirical validity in various policy-analytical studies (see e.g., Capello *et al.*, 1999 and Nijkamp *et al.*, 1994). We will now concisely describe the five factors that are presented here. *Economic capital*: this component refers to the economic foundation that is necessary for an efficient operation of a sustainable urban area. In particular, two forces are relevant here:

- open competition among many actors (to induce a creative search for new decisions and courses of action)
- entrepreneurship in business life (to stimulate innovativeness)
- *Ecological resources*: this driving force is particularly concerned with eh environmental basis that is a prerequisite for ecologically sustainable development. Two elements are particularly important in this context:
- quality of life for urban residents (e.g., clear air, low noise levels, clear water and soil)
- provision of urban green (e.g., urban parks, supply of ponds, lakes and canals, an open space if order to offer a sufficient degree of biodiversity
- *Technological systems*: this concept is not only related to the technological advances, but in particular to soft factors, such as:
- the creation of an innovative culture by encouraging an active role of launching actors (both producers and consumers)
- the marketing of a sustainable image of the city of the city concerned (through pro-active public involvement)
- *Geographical infrastructure*: this notion addresses in particular the network character of cities (both physical and non-physical) and is particularly concerned with:
- accessibility (by exploiting the hub character of a city)

- connectivity (by stimulating the e-function of the city in a world-wide competitive setting)
- *Social suprastructure*: this factor represents the society's drivers which create a socially sustainable society, in particular:
- creativity (a potential human asset that forms the foundation of innovative ideas)
- diversity (a systemic notion that supports open mindedness, coping with stress etc.)

The fulfilment of these five Pentagon factors will most likely have a positive impact on the ecology and economy of SIC, in particular, productivity rise, feelings of well-being, creativity and innovativeness, and orientation towards scientific and educational literacy.

Conclusion

Cities are the geographical hubs (virtual and real) in a modern networked space-economy. They are the source of progress and global orientation, and hence deserve full-scale attention of economists, geographers, planners, sociologists, political scientists and urban architects. Thus, cities – and more generally, metropolitan areas – will continue to be engines of economic growth, creativity and innovativeness. Clearly, R&D and investments in education and knowledge will be essential in this context, as these elements are the key ingredients for productivity enhancement at local and regional levels. This calls for pro-active and open-minded governance structures, with all actors involved, in order to maximize the socio-economic and ecological performance of cities and to cope with negative externalities and historically-grown path dependencies.

The complexity of modern cities as SIC calls for a systems economic approach which should generate promising methodological and planning perspectives that favour the sustainability of urban systems. Elements of such a future-oriented research agenda are:

- A system of solid meta-analyses that would be able to identify growth-inducing and growth-inhibiting factors of dynamic cities, based on a series of quantitative impact assessment studies;
- The development of comparative efficiency studies on urban growth performance (including resilience factors) in order to generate lessons from urban efficiency differentials;
- The development of a system of computable urban equilibrium models, put in the broader context of complex urban systems;
- A thorough quantitative analysis based on testable models of the strategic position (including background factors) of cities on hubs ('leaders') in a global network system;
- A solid statistical analysis of creative future scenarios related to urban complexity in multi-actor networks, as a support tool for strategic policy-making;
- An analytical synthesis of micro-, macro- and socio-economic theory geared towards the explanation (anatomy) and policy strategy (therapy) of critical success factors for a globally sustainable development of cities.

The research challenges for modern cities are vast, but are justified by the following quotation: "*The city is not only the place where growth occurs, but also the engine of growth itself*" (Duranton, 2000). With more people living in cities, there is a need to look at the economic geography of our world from an urban systems economics perspective.

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